Research Topic for the ParisTech/CSC PhD Program

Field: 8. Material Science; 2. Chemistry, Physical Chemistry and Chemical Engineering
Subfield: Material Science; Chemistry
ParisTech School: ESPCI Paris, 10 Rue Vauquelin, 75005 Paris
Title: Upconversion Organic-Inorganic Hybrid Materials for Optoelectronics
Advisors: Dr. Lionel Aigouy (lionel.aigouy@espci.fr) and Dr. Zhuoying Chen (zhuoying.chen@espci.fr)
Web sites: http://www.espci.fr/recherche/labos/lpem/mnc/index.html, and http://optoelec.lpem.espci.fr

Short description of possible research topics for a PhD:

Photon upconversion, a phenomenon to convert low energy photons into high energy ones, has been a fascinating topic since its discovery. Over the last decades, various upconversion material systems have been identified which can be classified as systems relying on rare-earth elements and systems without rare-earth elements. Concerning rare-earth systems, major examples mainly include fluoride, oxide and oxysulfide matrixes (host) doped or co-doped by trivalent lanthanide cations capable to perform upconversion through a multi-photon absorption by the sensitizer (e.g. Er^{3+}) and subsequent energy transfer to the emitter (e.g. Yb^{3+}, Er^{3+}). By comparison, non-rare-earth systems rely mainly on the energy transfer of excitons from sensitizers (e.g. colloidal quantum dots, tetracene molecules) to the spin-triplet states of annihilators (e.g. ruberene, pentacene) where two triplet excitons on neighbouring molecules interact to generate one higher-energy singlet excited state (i.e. triplet-triplet annihilation). Upconversion materials have many applications in fields including biomedical engineering, optical amplification, thermal sensing, photodetection, night vision, and solar energy harvest [*Nat. Photonics* 10, 31-34 (2015), *Chem. Rev.* 115, 395-465 (2015)]. Currently in our laboratory the synthesis of upconversion nanocrystals (NCs) have been established (Figure 1).

In this thesis, we aim to study a series of upconversion NCs and organic-NC hybrids for optoelectronic applications such as photovoltaic devices and photodetectors. Both rare-earth and non-rare-earth routes will be studied in order to obtain the best upconversion systems for the targeted application. This project will start with learning the colloidal synthesis for upconversion NCs as well as published synthetic protocols to form NC/organic molecule upconversion hybrids. Structural and optical characterizations will be performed on the obtained upconversion systems. The student will then focus on the design and fabrication of a hybrid photodetector or photovoltaic structure where the upconversion systems will be applied to detect/harvest near-infrared photons (on which the photodetector itself, without upconversion systems, has no sensitivity). Device performance will be characterized in-house providing feedbacks to the material synthesis. In addition to the design of novel photovoltaic and photodetector devices, the obtained upconversion materials will also be used for thermal and plasmonic imaging experiments in nanooptics.

Required background of the student: Materials Science, or Chemistry. Motivated for experiments and good in English.

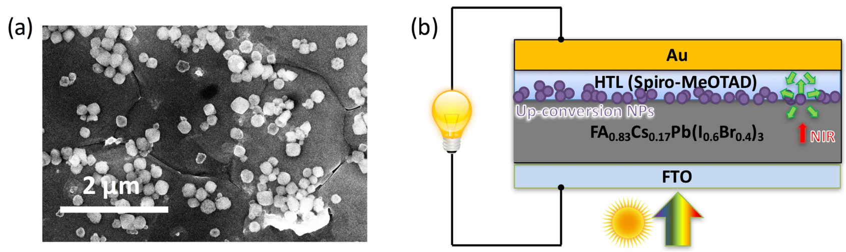

Figure 1. (Left) KY_7F_{22} nanocrystals co-doped with Yb^{3+} and Er^{3+} deposited on $[HC(NH_2)_2]_{0.83}Cs_{0.17}Pb(I_{0.6}Br_{0.4})_3$ perovskite layer. (Right) Schematic describing a photovoltaic device structure applying upconversion nanocrystals in the hole-transport polymer.

2-3 representative publications of the group:

- "Microscopic Evidence of Upconversion-Induced Near-Infrared Light Harvest in Hybrid Perovskite Solar Cells", M. Schoenauer Sebag et al, *ACS Applied Energy Materials*, 1, 3537-3543 (2018)
- "Short-Wave Infrared Sensor by the Photothermal Effect of Colloidal Gold Nanorods", H. Xiang et al, *Small*, 14, 1704013 (2018)
- "Compact layer free mixed-cation lead mixed-halide perovskite solar cells", Z. Hu, *Chem. Comm.* 54, 2623-2626 (2018)